Propagation of epileptic spikes revealed by diffusion-based constrained MEG source reconstruction

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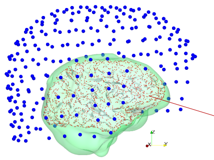
Goal: Study of the propagation of an epileptic spike.
Method: 1- cortex parcellation via structural information coming from diffusion MRI (dMRI)
2- MEG inverse problem on a parcellated source space
3- study of the propagation of an epileptic spike via the active parcels
Results on real data allowing to study the spatial propagation of an epileptic spike.

1 Preprocessing

1- Co-registration of the T1wMRI and dMRI [soft FSL]

2- Surface meshes extraction [soft Freesurfer]

3- Computation of the leadfield matrix G [soft OpenMEEG]



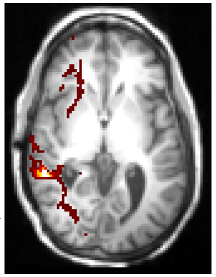
Each vertice of the WM/GM boundary mesh is:
- Source of a magnetic field
- Seed for tractography

2 dMRI-based cortex parcellation

Connectivity profile of a source CP:

CP(i) = connectivity value between the source and the ith voxel.

4- For each source:
Computation of its connectivity image.



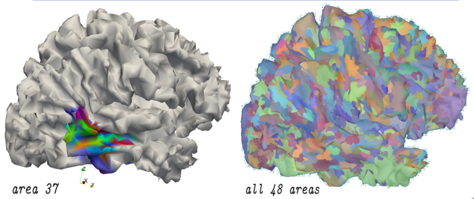
Tool: Probtrackx [soft FSL]

5- Pre-clustering via Brodmann's atlas

For each Brodmann area, clustering of sources having a close connectivity to all sources:

5.1- Computation of the CP-based correlation matrix R [5]

5.2- K-means algorithm on R



3 MEG inverse problem with parcellated source space

We reduce the inital distributed source space S into s in accordance with the cortex parcellation:

$$S = P \times s \text{ with } P(i,j) = \begin{cases} 1, \text{if source i is in area j} \\ 0, \text{if not} \end{cases}$$

and compute the reduced leadfield G_P for the parcellated source space s: $G_P = G \times P$

Thus, the MEG inverse problem on the parcellated source space using Tikhonov regularization becomes :

$$\min_s ||M - G_P s||^2 + \lambda ||s||^2$$

where M contains the MEG measurements.

4 Study of the propagation of an epileptic spike

At each time sample, we want to determine the cortical areas at the origin of the activity. We call $\mathscr{S}_t$ the set of these areas, for a time sample t

For each time sample t, we compute the power $\mathscr{P}_{p,t}$ of each area p on a sliding time window $[t-\alpha, t+\alpha]$:

$$\mathscr{P}_{p,t} = \sum_{i=t-\alpha}^{t+\alpha} |s(p,i)|^2.$$

$$\mathscr{S}_t = \{p_a : \mathscr{P}_{p_a,t} > F * \max(\mathscr{P}_{p,t}), \forall p\}$$

with F a pourcentage.

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[3] C. Baumgardner etal, Propagation of interictal epileptic activity in temporal lobe epilepsy, Neurology, 1995.
[4] AC. Philippe etal, Cortex parcellation via diffusion data as prior knowledge for the MEG inverse problem, ISBI, 2013.
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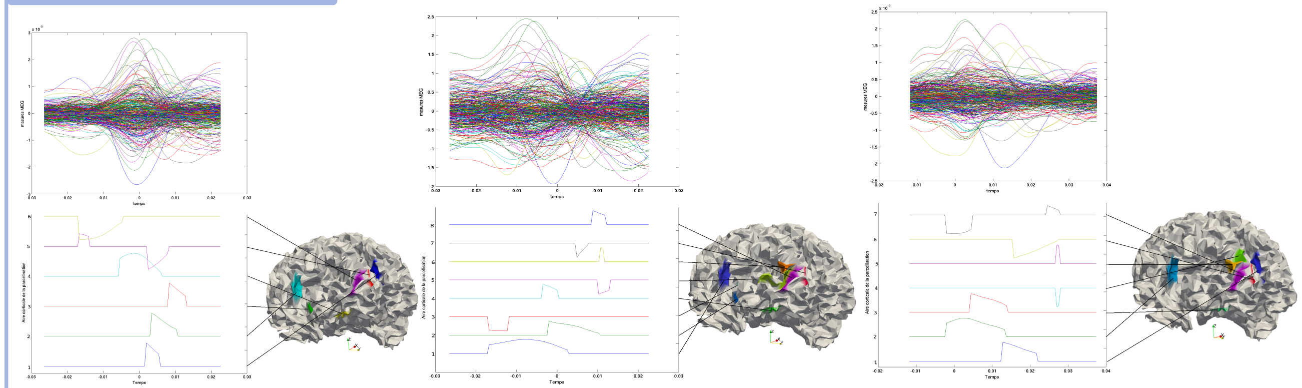
5 Results & Conclusion

Results on 3 epileptic spikes of a single subject.



- Almost the same parcels are activated for all epileptic spikes.
- The direction of propagation changes: from the back of the frontal lobe to the front or opposite direction.
- The time of activation of each parcel characterizes the spike.

- The parcellation allows an easier representation of source space.
- The method reveals differences between spikes (direction of propagation and time of activation of parcels).
- Future works will be to analyse the structural network supporting the propagation.

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